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18. B. Maroney and J. Gates, "Seismic Risk Identification & Prioritization in the CALTRANS Seismic Retrofit Program", material provided for the Cajon Pass Lifeline Study, September 1990.

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20. C. Rojahn, C. Scawthorn, and M. Khater, "Seismic Vulnerability of Lifelines in the Conterminous United State", ATC-25, in press.

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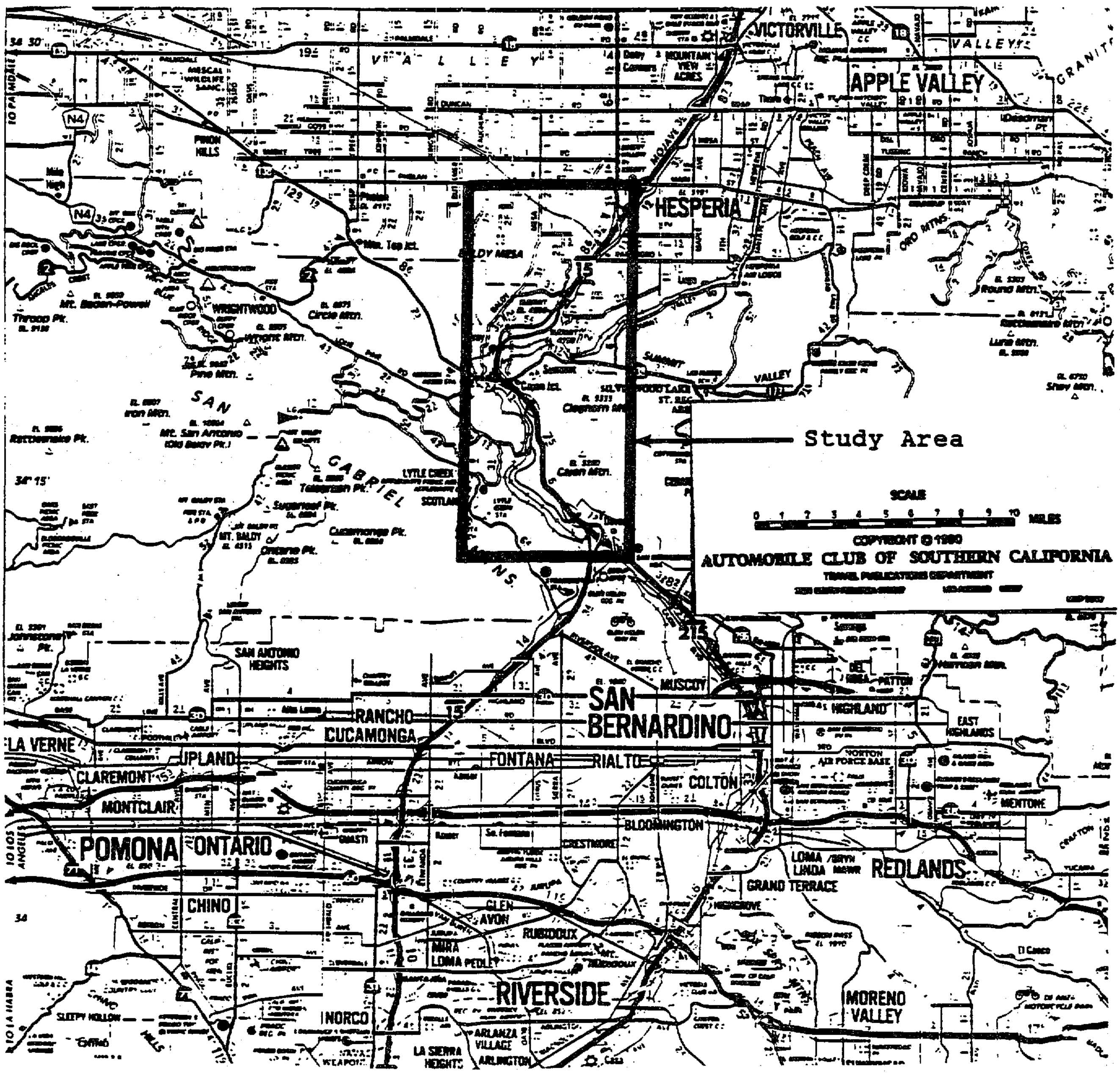
5.0 APPLICATION THE METHOD TO CAJON PASS

5.1 Data Acquisition

The following material demonstrates the application of the analysis method described in Section 4.0. The first step of the process is to assemble the data base that describes the lifelines and their routes in the study area as well as the geologic and seismic situation. The earlier Cajon Pass study[1] provides most of the needed information. It should be consulted for specifics about each lifeline and when it was installed.

Figure 5 shows the Cajon Pass study area and its relationship to other cities in California. It is used with the permission of the Automobile Club of Southern California (it is copied from the San Bernardino County and Las Vegas Area map). It shows that the Cajon Pass canyon (which is about 10 miles northeast of San Bernardino) is a natural access route between the San Gabriel Mountains to the

Figure 5, MAP OF THE GENERAL LOCATION OF THE CAJON PASS STUDY AREA



west and the San Bernardino Mountains to the east. The Pass connects the Los Angles Basin in the south to the high desert regions to the north. The City of San Bernardino is about 10 miles southeast of the mouth of the Pass.

U.S. Geological Survey quadrangle maps (7.5 minute series topographic maps published in 1988) were used to obtain more detail and to develop a plan for a site survey. The site survey was then conducted. It identified additional lifelines that were not identified on the 7.5 minute quadrangle maps, which emphasizes the need to conduct actual site surveys to validate the published information on lifeline systems. With the map and site visit information as a background, the individual lifeline owners were contacted and meetings were held with their staff to obtain more details on the location, capacity, design basis, operating and maintenance history, and emergency response systems in place for each lifeline. The Cajon Pass site was revisited to validate our understanding of the actual siting conditions, and in some cases this led to additional visits and discussions with the lifeline owners to resolve questions. This emphasis on the lifeline data acquisition and validation is very important, as there are over 100 discrete locations (which include over 250 separate combinations of collocated lifeline components) in the Cajon Pass study area where different lifeline components are in close enough proximity that it was necessary to evaluate their potential for collocation impacts.

Figure 6 is a plot of the communication, electrical power transmission, natural gas pipelines, petroleum products pipelines, railroad, and highway lifelines overlaid upon the U.S. Geological Survey's quadrangle map of the study area. Figure 6 shows several important items. First, the Pass is crowded with the lifelines traveling in a general north-south orientation through the middle of the study area. Second, the lifelines are clearly routed in a utility corridor. Since the bed of the Pass varies from about 0.5 miles near Blue Cut (which is located in about the center of the figure) to over several miles wide at most other regions, topology requirements alone would not require the observed congestion. The conclusion reached was that routing criteria such as aesthetic, cost, land use, and environmental considerations have had the controlling impact on the lifeline routing decisions.

There are especially congested areas near the intersection of Highways I-15 and I-215 in the southeast corner of the study area, near Blue Cut in the center portion of the study areas, and south and separately north of the intersection of Highway I-15 and State Highway 138. In addition, there are crowded areas for several of the lifeline systems, for example, near the railroad summit of Cajon Pass where natural gas pipelines, fiber optic lines, and the railroads are closely located. Also in the northern portion of the study area it is crowded where the two petroleum product pipelines and two fiber optic conduits parallel one set of high voltage power lines and also along Baldy Mesa Road where the two petroleum

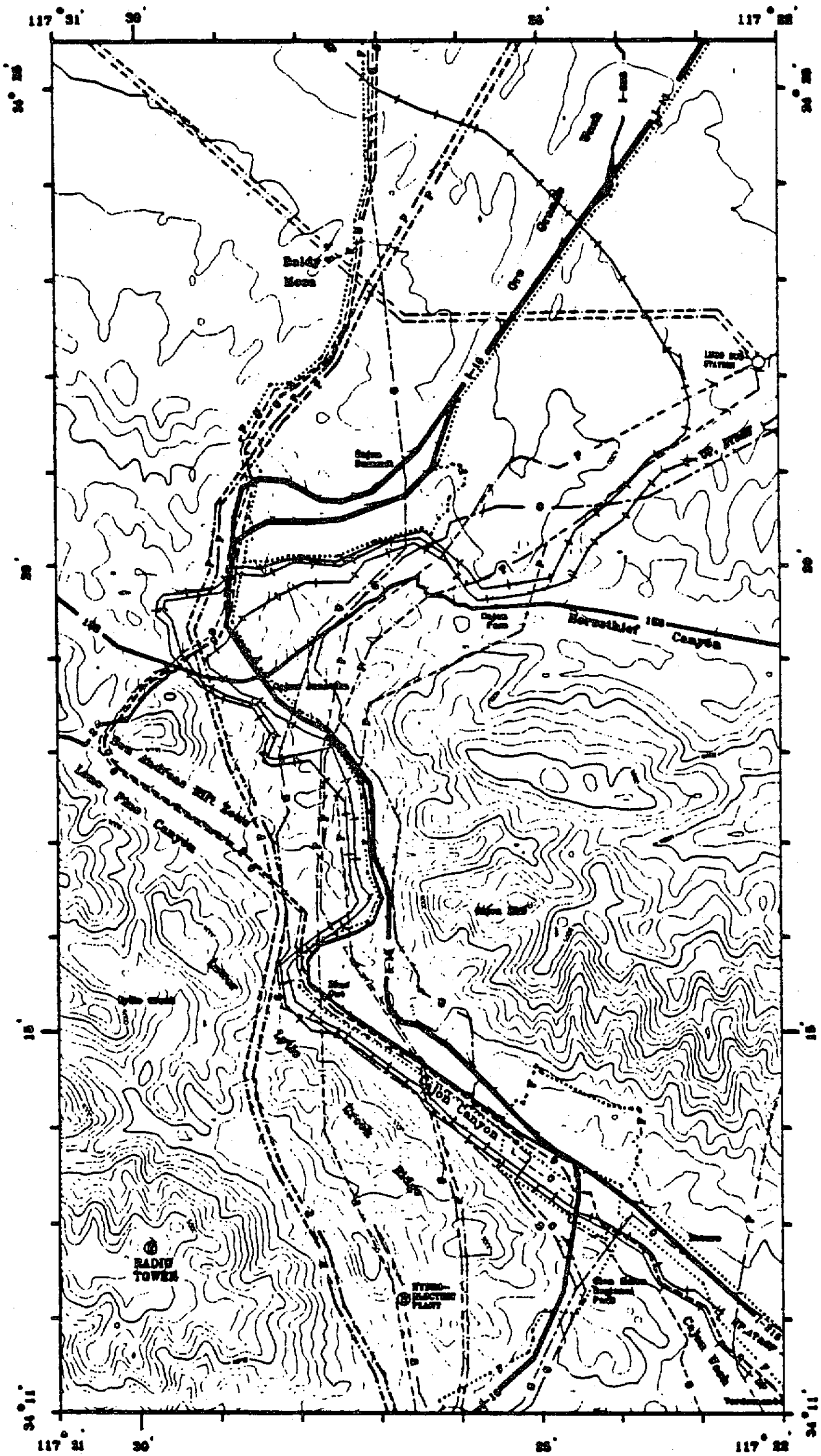
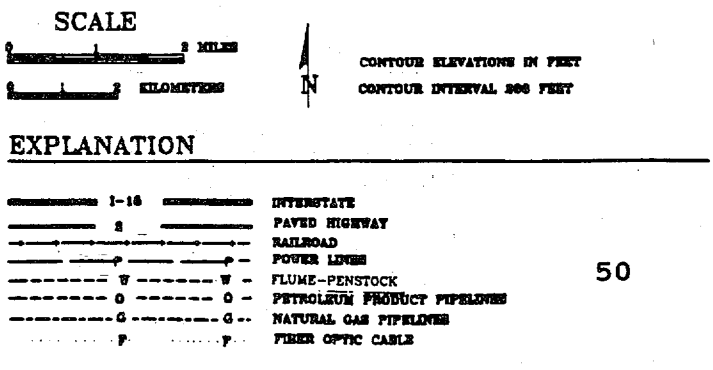


Figure 6, A COMPOSITE OF THE LIFELINE ROUTES AT CAJON PASS



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product pipelines, the fiber optic conduits, and a natural gas pipeline all are routed alongside of the road bed. The two petroleum product pipelines, a natural gas pipeline, and two high voltage power lines cross the San Andreas fault in Lone Pine Canyon at approximately the same region. The unfortunate routing for several miles of the petroleum products pipelines along the San Andreas fault's rift zone does not enter into the current study since there are no collocated lifelines of interest along that route. Finally, there are collocated railroad lines, power lines, a natural gas pipeline, the petroleum products pipelines, and the fiber optic conduits parallel to I-15 between the I-15/I-215 interchange and Blue Cut.

Figure 7 is another composite map of Cajon Pass. Each of the 101 collocations that were analyzed during this study are shown on this figure. Within those 101 locations, over 250 individual collocations occurred. This emphasizes how siting decisions have resulted in crowded collocation conditions, even though there is sufficient space to avoid most of them. Although there are several broad grouping of lifeline intersections, it is clear that they occur throughout the entire length of the study area.

The seismic and geologic information was also obtained during the data acquisition phase of the study. A sensitivity evaluation of six postulated earthquake events was performed to guide the selection of the event for use in the study. Other[2,3] studies were consulted to help select the earthquake events. The six events were:

1) The 1857 Ft. Tejon earthquake on the San Andreas fault. This was 300 km long fault with a magnitude 8.3 earthquake, and with the southern edge of the surface displacement located just north and west of Blue Cut.

2) An earthquake on the southern segment of the San Andreas fault. This was a 200 km long fault of 7.8 magnitude. The northern edge of the surface displacement was placed just north and west of Blue Cut.

3) An earthquake similar to event 1, except that the southern extreme of the surface displacement was moved about five mile further east into the study region.

4) An earthquake similar to event 1, except that the length of the fault was reduced to 105 km. This resulted in a 7.7 magnitude earthquake.

5) An earthquake similar to event 1, except that it was centered about the Cajon Pass. This resulted in a 8.3 magnitude earthquake.

6) A earthquake of 94 km length, but placed on the San Jacinto fault. This resulted in a 7.5 magnitude earthquake.

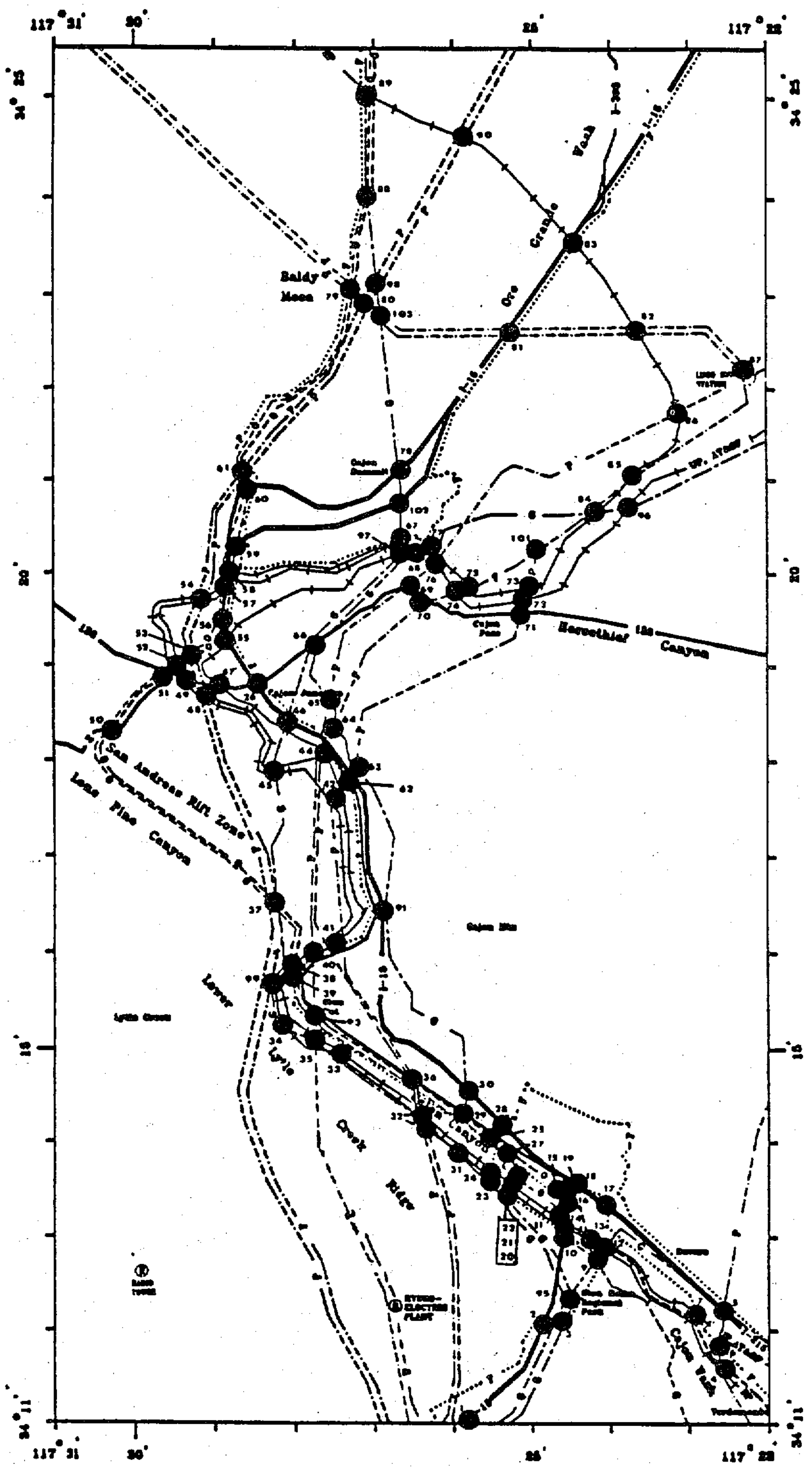
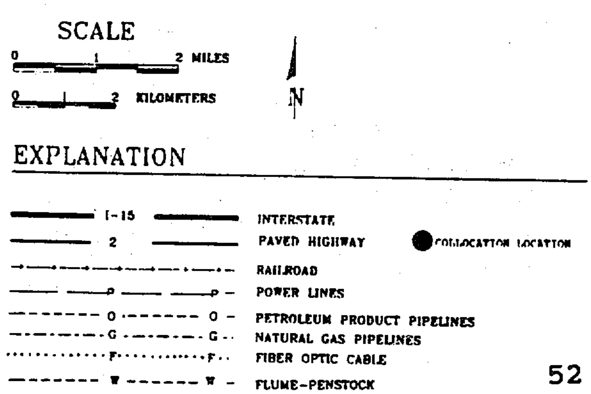


Figure 7, IDENTIFICATION OF LIFELINE COLLOCATION AT CAJON PASS



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The sensitivity study was performed with the QUAK2NW3 computer code[4,5] developed by the U.S. Geological Survey. Based on the study, the ground shaking intensities were relatively insensitive to the changes in fault rupture length The conclusions reached was that the 1857 Ft. Tejon earthquake was a reasonable choice for the study. It did not produce the most intense shaking, nor was it the least intensive. However, by using it for the present study, it will be possible to compare our solutions for earthquake intensity with those of previous researchers[5,6]. That comparison showed general agreement except at the fault rift zone. There the QUAK2NW3 program predicted lower shaking intensities than those reported by Davis[6]. After discussions with Davis, it was decided to increase the predicted MMI shaking intensity along the San Andreas fault zone by one level from VIII to IX. This accounts for the greater impacts that are expected to be associated with the fault displacement and is consistent with the work of Davis.

The areas of potential liquefaction were determined by examining the water well data for the Cajon Pass, and supplementing it with other regions high water table as determined by the site reconnaissance visits. Regions of high water table were correlated to alluvial deposits to identify the liquefaction susceptible regions. The historical landslides were identified[6,7,8] and the method of Legg (see Section 4.2, Table 7) was applied. A computer-based check of the soil conditions at the Cajon Pass was used to assure that the Legg method was applied at each slope of interest. The landslide predictions based on the Legg model agreed quite well with the record of historical landslides (that is, the Legg model prediction included the historical landslides, but it also identified many more potential areas of landslide).

Figure 8 presents the summary of the calculated seismic and geologic conditions overlaid upon the lifeline routes. Although the figure is complex and filled with data, it does highlight some important information. In the figure the shaking intensities are shown with various levels of shading. The highest intensities, MMI = IX, are along the San Andreas fault rift zone. On the map they are shown as solid lines where the fault is well located, dashed where its location is estimated, and circled when it is hidden by younger rocks. The potential landslides are predominantly south of the San Andreas fault and lie in a southeast trend. There are four important regions of potential liquefaction: just south of Cajon Junction, at Blue Cut where they coincide with potential landslide regions, southeast of Blue Cut about two miles northeast of the I-15/I-215 intersection, and just south of the I-15/I-215 intersection.

Figure 8 shows that many of the conditions of high MMI value, landslide, and liquefaction overlap. This is important to note because the lifeline components in the study area (with the exception of some bridges) are not very sensitive to shaking damage. MMI values of VIII generally would only cause damage state

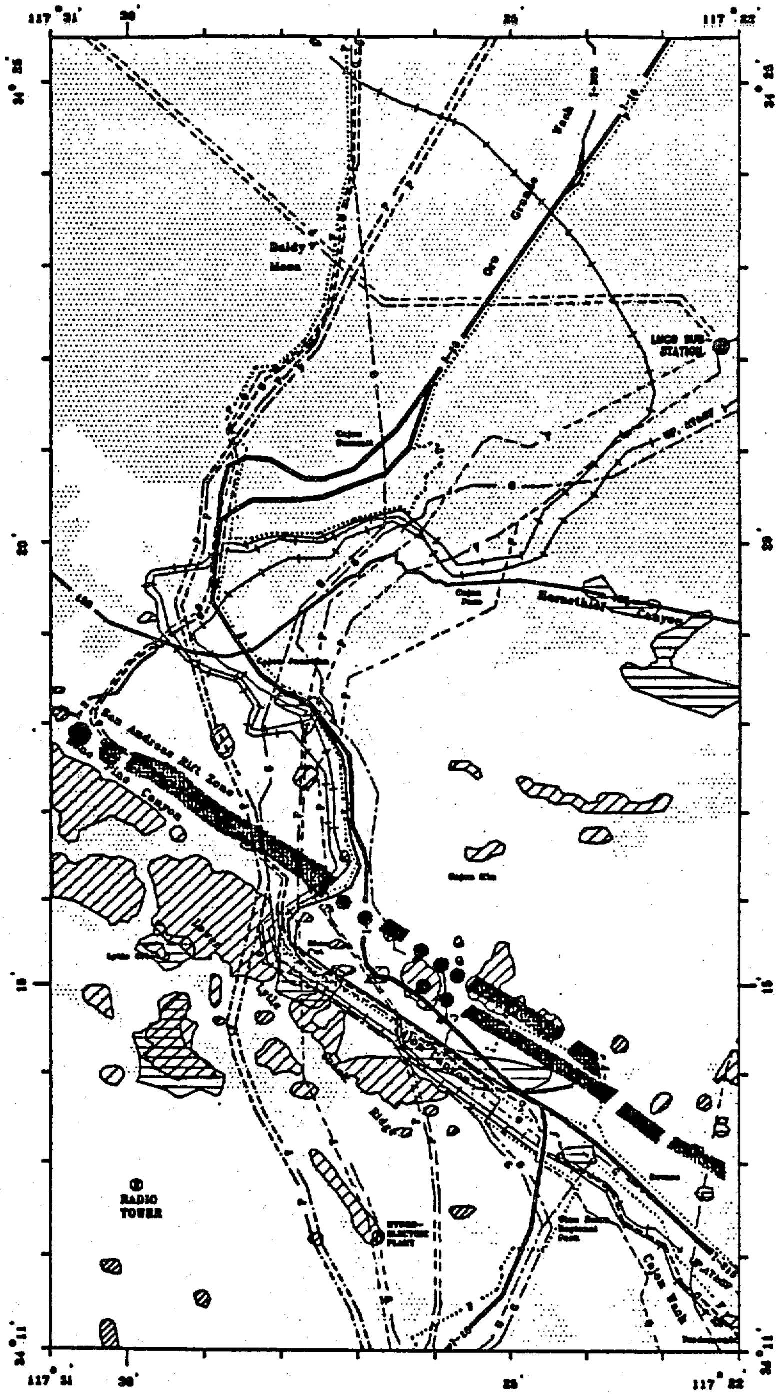
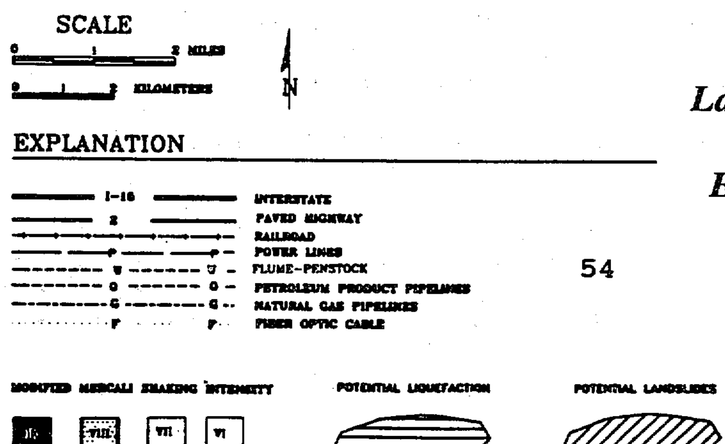


Figure 8, LIFELINE ROUTES WITH EARTHQUAKE SHAKING INTENSITY, AND POTENTIAL LANDSLIDE AND LIQUEFACTION AREAS



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